CHAPTER 13

Effects of Oil Spills on the Environment

Oil spills have many adverse effects on the environment. Oiled birds are one frequent and highly publicized outcome of oil spills, but there are many other less obvious effects such as the loss of phytoplankton and other microscopic forms of life. These effects are varied and influenced by a number of factors. This chapter reviews the effects of oil on the environment and touches on how damage from oil spills is assessed.

Before discussing the actual effects of an oil spill on various elements of the environment such as birds and fish, the types of effects will be discussed. Toxic effects are classified as chronic or acute, which refers to the rate of effect of toxin on an organism. Acute means toxic effects occur within a short period of exposure in relation to the life span of the organism. For example, acute toxicity to fish could be an effect observed within 4 days of a test. The toxic effect is induced and observable within a short time compared to the life span of the fish. Chronic means occurring during a relatively long period, usually 10% or more of the life span of the organism. It might take a significant portion of the life span for a chronic toxic effect to be observable, although it could have been induced by exposure to a substance that was normally acutely toxic. Chronic toxicity refers to long-term effects that are usually related to changes in such things as metabolism, growth, reproduction, or ability to survive.

The effects of exposure to a toxic substance can be lethal or sublethal. Lethal exposure is often described in terms of the concentration of the toxicant that causes death to 50% of a test population of the species within a specified period of exposure time. This is referred to as the LC$_{50}$. For example, tests of the effects of various crude oils on *Daphnia magna*, the water flea, show that 5 to 40 mg/L of the oil for a period of 24 hours is lethally toxic. The units of milligrams/litre (mg/L) are approximately equivalent to parts-per-million (ppm). Sublethal means detrimental to the test organism, but below the level that directly causes death within the test period. For example, it has been found that a concentration of 2 ppm of crude oil
in water causes disorientation in *Daphnia magna* when the organism is exposed for 48 hours.

Oil can affect animals in many ways, including changing their reproductive and feeding behaviour and causing tainting and loss of habitat. Oiling of more highly developed animals such as birds may result in behavioral changes, such as failure to take care of their nests, resulting in the loss of eggs. Even a light oiling can cause some species of birds to stop laying eggs altogether.

Feeding behaviour might also change. Seals sometimes react to oiling by not eating, which compounds the negative effects of the oil. The loss of an organism’s habitat due to oiling can be as harmful as direct oiling because alternative habitats may not be available and the animal can perish from exposure or starvation.

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Finally, tainting becomes an issue with fish and shellfish after an oil spill. Tainting occurs when the organism takes in enough hydrocarbons to cause an unpleasant, oily taste in the flesh. These organisms are unsuitable for human consumption until this taste disappears, which could take up to a year after the spill. After an oil spill, food species in the area are often tested using both chemical methods and a taste panel and the area is sometimes closed to commercial fishing as a precaution.

Oil can enter organisms by several exposure routes: physical exposure, ingestion, absorption, and through the food chain. Animals or birds can come into direct contact with oil on the surface of water, on shorelines, or on land. The effects from this form of exposure are usually quite different than the effects of direct ingestion. Ingestion occurs when an organism directly consumes oil, usually by accident as in the case of birds when oil is ingested as they preen or groom their feathers.

Absorption of volatile components of oil is a common method of exposure, especially for plants and sessile (immobile) organisms, although it also occurs in birds and mammals. Fresh crude oil has a relative abundance of volatile compounds such as benzene and toluene that are readily absorbed through the skin or plant membrane and are toxic to the organism.

After a spill, organisms can also be exposed to oil that passes through several organisms via the food chain. Bioaccumulation, the accumulation of toxins in the flesh, rarely occurs since the components of oil are generally metabolized by the receiving organism.

The effects of oil on the flora and fauna of a region are influenced by many factors, including the sensitivity of an organism, its recovery potential, its tendency to avoid an oil spill, its potential for rehabilitation, and the particular life stage of the organism.

Sensitivity describes how prone an organism is to the oil and any effects. It varies with such factors as species, season, and weather conditions. Often sensitivity maps used by spill cleanup crews include information on the vulnerability of local species to oil spills.

Recovery potential refers to the ability of organisms or ecosystems to return to their original state, or the state they were in before the spill event. Recovery time varies from days to years. For example, the ecosystem of a rocky shoreline can recover from an oil spill within months as organisms from unoiled areas can move in and restore the population.

Avoidance is another response to oil spills. Some species of fish, seals, and dolphins will avoid surface slicks and move to unoiled areas. Some birds, however, are attracted to oil slicks, mistaking them for calm water. Further research is being done in this area.

Another factor that influences the effects of oiling is the potential for rehabilitation of oiled animals. Birds, otters, and seals are often cleaned, treated, and returned to the environment. Many species cannot be rehabilitated, however, as they are difficult to catch and the stress of being caught and kept in captivity may be worse than the effects of oiling.

And finally, the effects of oil on any species often depend on the age or life stage of the organism. For example, juveniles of a species are often much more
sensitive to oiling than the adults and seals are much more sensitive to oiling when they are molting.

Aquatic Environments

The sea includes a wide variety of ecosystems, species, and habitats. When looking at the effects of oil spills, it is convenient to divide these into fish, plankton, benthic invertebrates, epontic organisms, marine mammals, intertidal and shoreline organisms, marine plants, and special ecosystems.

Many freshwater biota respond to oil in a manner similar to their salt water counterparts. Although freshwater studies have not been as extensive as those for marine situations, few differences were noted. While oil is less soluble in freshwater, this is largely offset by the fact that many freshwater bodies are much shallower than oceans. A spill in a slough or pond can easily result in toxic concentrations throughout the entire water column. The high water circulation in most rivers, however, means that hydrocarbon concentrations in the water are diluted quickly.

Fish

There is often concern about the effect of oil on fish, from both an environmental and a commercial viewpoint, as fish are an important food source. Both pelagic (mid-water) and demersal (bottom-dwelling) fish are exposed to toxicity primarily through aromatic hydrocarbons in the water column. The concentration of aromatic

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hydrocarbons in oils varies, as does the toxicity of the different aromatic compounds. Although lethal concentrations are rarely found in open seas, such concentrations can occur in confined waters, such as bays and estuaries, directly under or near spills. Whereas high concentrations of oil have caused massive fish mortality in

*Photos 139 (above) and 140 (below)*  Wildlife are sometimes attracted to oil spill operations. This beluga whale is playing with the boom during an oil spill exercise. (Environment Canada)
some incidents, fish are more typically exposed to sublethal concentrations of hydrocarbons. Some concentrations of hydrocarbons that are lethal to various aquatic species, both fresh and salt water, are listed in Table 19.

The age of a fish is very important in terms of its sensitivity to hydrocarbons, with adult fish tending to be less sensitive than juveniles. For example, tests have shown that adult salmon are 100 times less sensitive to aromatic hydrocarbons than juvenile salmon. In turn, the juveniles are 70 times less sensitive than the salmon eggs. Several studies have shown that fish larvae or newly hatched fish are often more sensitive than fish eggs.

Other variables that determine the toxicity of hydrocarbons are the salinity and temperature of the water, the abundance of food, and the general health of the species.

Oil exposure can cause a range of physiological and pathological changes in fish, some of which are temporary and are not a risk to health or survival. Other sublethal effects such as the disruption of growth or decreased assimilation of food may affect long-term survival. Some of the effects noted on fish such as eye cataracts, structural changes of fins, and loss of body weight may be related to the stress of exposure and not directly to the hydrocarbons.

In controlled tests, some adult fish species avoided oil slicks on the surface or dissolved hydrocarbons in the water, but this behaviour has not been observed in

<p>| Table 19 Aquatic Toxicity of Water-soluble Fractions of Common Oils |
|------------------------|------------------------|------------------------|</p>
<table>
<thead>
<tr>
<th><strong>Oil Type</strong></th>
<th><strong>Specific Type</strong></th>
<th><strong>Species</strong></th>
<th><strong>Common Name</strong></th>
<th><strong>LC50</strong></th>
<th><strong>Time</strong></th>
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<tr>
<td>Gasoline</td>
<td>Daphnia Magna</td>
<td>water flea</td>
<td>20 to 50</td>
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<td></td>
<td>Artemia</td>
<td>brine shrimp</td>
<td>5 to 15</td>
<td>48</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>rainbow trout larvae</td>
<td>5 to 7</td>
<td>48</td>
<td></td>
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<tr>
<td>Diesel Fuel</td>
<td>Daphnia Magna</td>
<td>water flea</td>
<td>1 to 7</td>
<td>48</td>
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<td>Artemia</td>
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<td>1 to 2</td>
<td>48</td>
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<td></td>
<td></td>
<td>rainbow trout larvae</td>
<td>2 to 3</td>
<td>48</td>
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<tr>
<td>Light Crude</td>
<td>Alberta Sweet Mixed Blend</td>
<td>Daphnia Magna</td>
<td>water flea</td>
<td>6 to 12</td>
<td>48</td>
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<tr>
<td></td>
<td></td>
<td>Artemia</td>
<td>brine shrimp</td>
<td>10 to 20</td>
<td>48</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>rainbow trout larvae</td>
<td>10 to 30</td>
<td>96</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>frog larvae</td>
<td>3</td>
<td>96</td>
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<tr>
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<td></td>
<td>Artemia</td>
<td>fish</td>
<td>50</td>
<td>96</td>
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<tr>
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<td></td>
<td>scallops</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>salmon</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>crab</td>
<td>1</td>
<td>96</td>
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<tr>
<td>Heavy Crude Intermediate Fuel Oil</td>
<td>Arabian Heavy IFO-180</td>
<td>Daphnia Magna</td>
<td>water flea</td>
<td>5 to 8</td>
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<td>brine shrimp</td>
<td>0.8 to 4</td>
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<td>96</td>
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<tr>
<td>Bunker C</td>
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<td>water flea</td>
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<td></td>
<td></td>
<td>rainbow trout larvae</td>
<td>2</td>
<td>96</td>
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</tbody>
</table>

*LC50 is the lethal toxicity to 50% of the test population at the water concentration, specified in mg/L which is approximately the equivalent of parts-per-million.*
open water spills. The conclusion is that at least some species would avoid an oil spill on open water if they can escape it.

There is concern that oil spills could disrupt the spawning behaviour of anadromous species, such as salmon, that live their adult lives in salt water but return to fresh water streams to spawn. Tests have shown that, while salmon will sometimes avoid oil on open water, the exposure to oil may not badly disrupt their “homing instinct” as they tend to continue on to their freshwater home streams. Experience in actual spills has not been recorded.

There is no evidence that hydrocarbons bioaccumulate in fish or any other aquatic species. Rather, fish and other aquatic organisms tend to “depurate” or lose hydrocarbons that they have taken up. This process can take as long as one year from the time fish are exposed to high, sublethal concentrations of hydrocarbons, until the level is below detection.

Fish species that live or spend time close to the water surface, the shore, or the sea floor are the most vulnerable to oil spills. Species with eggs or larvae that stay close to the surface and those that feed on organisms near shorelines or on the sea bottom are at greatest risk. Fish that spend most of their life stages in open waters are rarely at risk.

**Plankton**

Plankton are small plants and animals that live in the water and include phytoplankton and zooplankton. Phytoplankton are microscopic plants such as algae...
and diatoms that live in the top layer of the water as they depend on light for photosynthesis. Zooplankton are microscopic animals that feed primarily on phytoplankton. Plankton are important because they are at the bottom of the aquatic food chain. Thus, oil ingested or absorbed by plankton is passed higher up the food chain, until it is finally ingested by fish and mammals.

Both phytoplankton and zooplankton vary in their sensitivity to whole oil or hydrocarbons in the water column. Plankton are killed by relatively low concentrations of oil, but are present in such numbers that lost individuals are replaced quickly with little detectable disturbance. Plankton also tend to depurate low concentrations of hydrocarbons within days. Some sublethal effects of oil on zooplankton include narcosis, reduced feeding, and disruption of normal responses to light.

### Benthic Invertebrates

The benthos refers to the environment on the bottom of bodies of water and includes plankton, fish, and other species already discussed. Benthic invertebrates that dwell on or in the sea floor include bivalves such as clams, polychaete worms, and many mobile crustaceans such as crabs, shrimp, lobster, and amphipods.

Benthic invertebrates are generally divided into two groups, benthic infauna that reside within the bottom sediments and benthic epifauna that live mostly on the top of the sediments. Mobile forms include the slow-moving starfish, gastropods, and sea urchins. Fast-moving species include amphipods and isopods, tiny invertebrates that are an important food source for fish, bottom-feeding whales, and some species of birds, which thereby pass contamination up through the food chain. These species have the advantage of being able to avoid contaminated areas or to quickly recolonize them whereas it can take years for sessile (or immobile) organisms to recolonize an area.

Benthic species can be killed when large amounts of oil accumulate on the bottom sediments. This can occur as a result of sedimentation, which is the slow downward movement of oil with or without sediment particles attached, or by precipitation down with or in plankton. Sometimes the oil itself is heavy enough to sink. High concentrations of hydrocarbons in the water column have killed epifauna, particularly in shallow areas or nearshore environments.

Several trends have been noted in the response of benthic invertebrates to oil. Larval stages are much more sensitive than adults, organisms undergoing molting are very sensitive, and less mobile species are more affected. Sublethal hydrocarbon concentrations cause narcosis, (death-like appearance when the organism is not actually dead) in most benthic invertebrates. The invertebrates often recover, although they may be more vulnerable to predators or to being swept away by currents. In 1996, a spill of diesel fuel off the east coast of the United States dispersed naturally into a nearshore region. The high level of hydrocarbons caused by dispersion narcotized or killed millions of lobsters that were carried onto the shore where those still alive were killed. Many other species were also killed including some clams and other benthic invertebrates.

Other sublethal effects of oil on benthic invertebrates include developmental problems such as slow growth, differential growth of body parts (deformity), changes
in molting times, and occasional anomalies in development of organs. Reproductive effects such as smaller brood sizes and premature release of eggs, reduced feeding, and increased respiration have also been noted in tests. Benthic infauna will sometimes leave their burrows, exposing themselves to predators. Starfish will often retract their tube feet and lose their hold as a result.

Benthic invertebrates can take up hydrocarbons by feeding on contaminated material, breathing in contaminated water, and through direct absorption from sediments or water. Most invertebrates depurate hydrocarbons when the water and sediment return to a clean state or if placed in a clean environment. In severe oiling, however, depuration can take months. Sessile (or immobile) species are obviously at a disadvantage and may perish from prolonged exposure to contaminated sediments. Generally, however, all benthic species are affected by a short-term dose of the hydrocarbons in oil.

**Epontic Organisms**

Epontic organisms are microscopic plants and animals that live under ice. Many of these are similar to plankton and have similar responses and sensitivities to oil. Epontic organisms are much more vulnerable than plankton, however, because oil remains directly under the ice, where these organisms live. Contact with oil causes death. The community may also be slow to recover because the oil can remain under the ice for a season or more, depending on the geographic location. As the major limitation to growth for these organisms is the lack of room under the ice as well as low light and temperature levels, the dead organisms are not quickly replaced.

**Marine Mammals**

The effects of oil spills on marine and other aquatic mammals vary with species. Seals, sea lions, walruses, whales, dolphins, and porpoises are discussed here, as well as the effects on polar bears and otters. Although these two species are not actually marine mammals, they spend much of their time in or near the water. All of these animals are highly visible and cause much public concern when oiled.

Seals, sea lions, and walruses are particularly vulnerable to oiling because they live on the shorelines of small islands, rocks, or remote coasts with few options for new territory. Despite this, only the young are killed by severe oiling.

External oiling of young seals or sea lions generally causes death because their coats are not developed enough to provide insulation in an oiled state. Oil is often absorbed or ingested and mothers may not feed their young when they are oiled. After a large oil spill in South America, about 10,000 baby seals perished when the beaches of their island were contaminated by oil. Not many adult seals perished at the same site, and those who did probably drowned.

Older seals, sea lions, and walruses can take a large amount of oiling without causing death. If lightly oiled, adult seals survive and the oil is slowly lost. Oiling of both adult and young causes the fur to lose waterproofing and buoyancy. It is not known if seals or their relatives would avoid oil if they could as this has not been observed at spill sites.

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This otter was lightly oiled, then captured, cleaned, and released. (Foss Environmental)

An oil spill fouled the rocks over which these seals move to get to the sea. Many seals were oiled as a result and, unfortunately, many of the younger ones subsequently died. (Environment Canada)
Brief exposure of seals, sea lions, and walruses to volatile oil causes eye irritation and longer exposure can cause more permanent eye damage. Several studies on ingested oil have shown that hydrocarbons accumulate in the blubber, liver, kidney, and other organs, although the levels diminish within a few weeks. Long-term effects have not been observed and are difficult to measure because of the difficulty of approaching relatively healthy seals, sea lions, and walruses.

Whales, dolphins, and porpoises can be exposed to oil in the water column or on the surface when they come up to breathe. Despite this, deaths of these species have not been reported as a result of a spill. This is probably due to a number of factors. Oil does not adhere to the skins of these mammals and, as they are highly mobile, they are not exposed for a long period of time. Whales and dolphins have been observed to avoid oil spills and contaminated waters. There is little information on the effect of ingested oil on whales and their kin, nor is there any evidence that hydrocarbons would be absorbed from water.

Polar bears spend much of their time in or near water, swimming between ice floes hunting seals. The potential for oiling is moderate. It was found that polar bears that are oiled ingest oil through grooming themselves, resulting in death or severe illness. Unfortunately, polar bears are attracted to oil, particularly lubricating oil, which they will actually drink. This generally causes temporary illness, but in the case of an oil spill, it could result in death. Few studies have been done of the sublethal effects of oil on polar bears as they are difficult to study.

Otters live on or near shorelines and spend much of their time on the water or feeding on crustacea on the sea floor. Otters are usually oiled in any spill near their habitats and can die after only a 30% oiling. Oil adheres to the otters’ fur causing
heat loss that is the most pronounced effect of oiling. Otters attempt to groom themselves after oiling and thus ingest oil, compounding their difficulty. As in the case of the polar bear, little is known about the effects of ingested oil. Some inflammation of the stomach and uptake of hydrocarbons have been observed. After light exposures, however, the animals appear to recover.

Oiled otters are often caught and taken to rehabilitation centres for cleaning by trained specialists. If caught and treated soon enough, some otters can be saved. Such rehabilitation is difficult and expensive, however, as animals may have to be kept for a month before release. In addition, many animals die after their release, possibly as a result of human handling.

**Intertidal Fauna**

Intertidal fauna include animals that live in the shoreline zone between the high and low tides. These organisms are the most vulnerable to oil spills because they and their habitat are frequently coated during oil spills. Typical fauna include the mobile crabs, snails, and shrimp, sessile (immobile) barnacles and mussels, and sedentary limpets, periwinkles, and tube worms. Heavy oiling will generally kill most species. The area does recolonize after the spill with the mobile species returning first, but recovery takes months and sometimes years. Recolonization by plants and sessile species is the major factor in site restoration.

As with other aquatic organisms, light oiling affects the immobile species most and most species will take up oil. Mussels and crabs in particular have been studied for their response to oil. Sublethal effects include reduced growth and reproduction rate and accumulation of hydrocarbons. Both mussels and crabs will depurate or cleanse themselves of hydrocarbons when placed in clean water. Crabs also show premature or delayed molting. Mussels reduce production of attachment threads, often causing the creature to let go of its hold on its feeding surface. Other intertidal fauna show similar behaviour as a result of light oiling.

Shoreline cleaning techniques have a strong affect on the recovery of an intertidal area. Very intrusive techniques such as washing with hot or high-pressure water can remove many of the food sources and thus delay recovery, despite removing all of the oil. Intertidal fauna are not highly affected by non-volatile residual oil unless they are coated with it. Recovery is fastest in those areas where oil is removed rapidly after a spill using a non-intrusive technique such as cold water, low-pressure washing.

**Marine Plants**

Marine plants cover a wide spectrum of plant families and algae. Intertidal algae, macro-algae, and sea grasses are of particular interest during oil spills.

Intertidal algae are an important food source for much of the intertidal fauna and like the fauna can be severely affected by an oil spill. Although readily killed by even a moderate oil spill, intertidal algae are usually the first biota to recover after a spill. This algae grow on rock and sediment surfaces and will not recolonize if these surfaces are still heavily oiled with a light oil. Algae will re-establish on
oil-coated rocks if the oil is weathered and no longer gives off volatile compounds. Like intertidal fauna, algae are also vulnerable to intrusive cleaning techniques such as washing with hot or high-pressure water. In fact, more algae are killed by these techniques than by oil. Sublethal effects include reduced reproduction and respiration rates and changes in colour.

Macro-algae include two common groups of plants in North America, *Fucus* and kelp, both of which include many species and sub-species. *Fucus*, which often inhabit the lower intertidal and subtidal zones, are not particularly susceptible to oiling because a mucous coating prevents the oil from adhering to the plant. A heavy oil will cover *Fucus*, however, and cause death or sublethal effects. Kelp generally lives in deeper water and is rarely coated with oil. Both *Fucus* and kelp will absorb hydrocarbons in the water column, but their effect, including death, depends on the length of time that the concentrations are present. A dose of a few hours will cause only slight and sublethal effects, while a moderate concentration over a few days could cause more serious damage and even death. Both plants will show sublethal effects of leaf loss, colour changes, reproductive slowdown, reduced growth, and accumulation of hydrocarbons. Both plants will also slowly depurate or cleanse itself of hydrocarbons in clean water. As these plants make up the habitat for complex ecosystems including many forms of animals and other algae, the entire ecosystem can be affected if they are damaged. Recovery for both types of plants and their habitats may take years.

Sea grasses generally inhabit the low-intertidal and subtidal zones and are extensive in any location around the world. Eelgrass, which is the common species in North America, is a vascular plant similar to most common water plants. Sea grasses are sensitive to hydrocarbon uptake and oiling. Because direct oiling rarely occurs, uptake of hydrocarbons from the water column is the main concern. Eelgrass is killed by moderate hydrocarbon concentrations in the water for a few hours or low concentrations for a few days. Eelgrass will show similar sublethal effects as kelp and *Fucus* and will also depurate or cleanse itself of hydrocarbons. A bed of eelgrass killed by an oil spill may take several years to recover.

**Special Ecosystems**

Salt or brackish marshes are important ecosystems because they are the habitat of many birds and fish that feed on a wide variety of invertebrates including crabs, snails, and worms. Some of these organisms burrow into the sediments providing a path for oil to penetrate if a spill occurs. These marshes are also the nurseries for many land and sea birds and animals. Salt marshes are especially vulnerable to oil spills because they are flooded at high tide and their complex surface traps large quantities of oil. It is also difficult to get into a marsh to assess the damage and clean up the oil.

Salt marshes are dominated by marsh grasses, the predominant one in temperate climates being *Spartina* and, in the Arctic, *Puccinellia*, which has similar characteristics. The outer fringes of marshes are dominated by shrubs such as sedges. Marshes also export a large amount of plant detritus back to the sea, which contributes to the food chains of connecting water bodies.
The effects of oil on a marsh depend on the amount and type of oil. Light to moderate amounts of a weathered oil or an oil that does not penetrate significantly will not result in massive mortality and the marsh can recover in as little as one to two years. Heavy oiling by a light oil that penetrates the sediments can cause heavy mortality and the marsh can take up to 10 years to recover. Due to the dynamic nature of marshes, i.e., constantly changing, oil can be covered and retained in relatively unweathered condition for decades. Massive oiling causes loss of the plant cover, which would also affect the animals and birds living in the marsh. As Spartina propagates from special root parts, any cleaning activity that destroys these will kill the plants. Marshes are very sensitive to physical disturbance and intrusive cleanup could easily cause more damage than the oil itself.

Arctic environments are often cited as a special case for oil spills, but in fact, extensive work on the toxicity and effects of oil have shown that Arctic species are about equally sensitive to oiling as their southern equivalents. The impact of an oil spill is increased, however, by the fact that the diversity of biota in the Arctic is very low and it takes longer to develop and grow. As oil takes longer to degrade and weather in the Arctic, toxic, volatile components are retained longer. For all these reasons, recovery from an oil spill is slower in an Arctic environment than in temperate and tropical zones.

Coral reefs occupy a large part of the seas in the tropics of the Pacific and the Caribbean. They are the most diverse and complex marine communities, supporting thousands of fish, algae, and invertebrate species. Studies and actual spills have shown that moderate concentrations of dissolved or dispersed hydrocarbons can kill both the coral and its occupants. Damage depends on the depth, with coral that is near the surface (down to about 6 m) being particularly vulnerable to oil. Many of the animals can repopulate the area rapidly, but since the coral is their primary support, full recovery depends largely on the recovery or recolonization of the coral. Once dead, the coral itself can be very slow to recover. Oil also has several sublethal effects on coral, such as slowed growth or respiration and unnatural coloration.

Mangroves are trees that grow along much of the shorelines in the tropics. They provide the habitat for a wide diversity of other life. Mangroves are supported by a complex, interlaced system of prop roots. The base of the roots is in low-oxygen soil and the trees take in air through breathing holes on the prop roots. If these are oiled and most of the breathing pores are plugged, the mangrove may die. The many other animals or birds supported by the trees are also at risk. It could take years to decades for mangroves to grow back in the oiled area. As with most plants, mangroves are subject to a number of sublethal effects including slower growth, loss of leaves, and changes in colour.

Unlike on water, oil spilled on land does not spread quickly and the effects remain local. Most types of oil will penetrate the soil and contaminate organisms in the soil. Diesel fuel was used at one time as a general vegetation killer. A full coating of fresh crude oil or diesel fuel will kill most plants and small trees on contact. Because of the low potential for affecting plants and less mobile animals directly on site, however, the effects of oil on land environments are not as great a concern as in marine environments. Oil spills on land are discussed in Chapter 12.

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Birds

Birds are the most visible biota affected by oil spills, especially in the aquatic environment. Oil contaminates feathers when the birds come into contact with slicks on water or shorelines. For sea birds, this is particularly dangerous because when their feathers are oily, their insulation and buoyancy properties are decreased. Once oiled, a bird rapidly loses its body heat, especially at sea and this may cause death. Oiled sea birds may stay on land where their temperature loss is not as great. In doing so, however, they are away from their source of food and may die of starvation.

Birds clean their plumage by preening and, in doing so, may ingest some of the oil. Birds may also ingest oil by eating oiled prey. While ingestion of oil may cause death, it is more likely to cause sublethal effects such as gastrointestinal dysfunction, liver problems, pneumonia, and behavioral disorders.

Contaminated birds may transfer oil to their eggs or young. It has been found that only a few drops of fresh oil can kill the young in an egg. Even when birds ingest only a small amount of oil, they may stop laying eggs or the number of eggs may be reduced. A small amount of oil can also affect the hatchability of the eggs.

Shoreline dwellers and feeders, which include ducks, gannets, and cormorants, are among the most susceptible birds to oiling. Auks and ducks that spend much of their time on the water are also susceptible to oil spills at sea. These birds feed by diving through the surface. Endangered species and those concentrated in a few colonies are particularly vulnerable as a spill could threaten the entire species.

In many spills, cleaning stations are set up to rehabilitate birds. Although techniques have improved greatly in the past few years, success rates are still poor as it is very stressful for a wild bird to be captured and handled. Less than half of the oiled birds that are cleaned and released actually survive. Only very sick birds can

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generally be captured and thus many of the birds brought to the treatment centres are often near death. Despite this, cleaning birds is easier than cleaning mammals and can reverse some of the effects of an oil spill.

**Damage Assessment**

Damage assessment is a new activity recently started in several countries. It involves a formal, structured examination of an oiled environment to determine how many of each species was affected by the oil spill. The objectives are to quantify the damage to the environment as much as possible and assess the total effects of a particular spill. Data are used to develop long-term restoration or cleanup plans if necessary, to assess costs, and to provide a database of spill damage. Damage assessment involves a thorough re-examination of the site through counts of plants and animals and comparison to the pre-spill condition. If information on the pre-spill condition is not available, the site is compared to a similar unoiled site nearby.
In the United States, damage assessment is becoming mandatory after oil spills and procedures have been developed to assess the costs of damages. A computer program and manual are being developed to assist in performing these assessments. Damage assessment is very difficult, however, especially estimating the cost of specific damage.

**Restoration**

Site restoration arises from damage assessment. Sites are restored by replanting trees and vegetation and recolonizing animals and birds at a site. While this appears simple and beneficial, it is fraught with difficulties and can upset the ecological balance in some areas if not carried out carefully. It is difficult and sometimes impossible to recolonize or move certain species of animals. Furthermore, a damaged site will often require a succession of different plant and animal species in recovery before a balance is achieved. If not carefully planned and conducted, human intervention can upset this natural succession process.

Despite these difficulties, many badly oiled sites have been restored to almost their original state in several years. For example, a badly oiled marsh in New Jersey that scientists thought would be impossible to restore began to recover a year after marsh plants were transplanted and some native animals were returned to the site.
Today, oil spill responders try to optimize net environmental benefits when considering how to deal with a spill. This simply means that the effects on the environment of whatever cleanup techniques are to be used are weighed against the damage to the site. In other words, the question is asked, will the cleanup process itself possibly cause more damage to the site than the oil would if it were left? Sometimes the decision is made not to clean up if an assessment shows that the cleanup itself will be intrusive. In the same way, the effects of the various cleanup techniques are also assessed and the least intrusive technique is chosen for a particular site.